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## PATENT ABSTRACTS OF JAPAN

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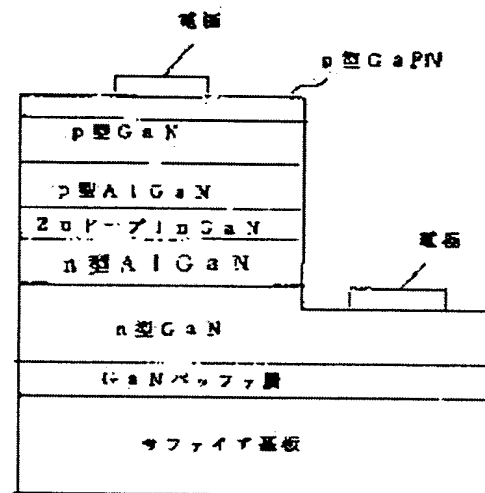
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## (54) SEMICONDUCTOR DEVICE HAVING CONTACT RESISTANCE REDUCING LAYER

(57)Abstract:

PURPOSE: To reduce contact resistance, and remarkably reduce the operating voltage of a light emitting device, by forming a thin film GaPN layer between an AlGaInN based layer and an electrode.

CONSTITUTION: In order to reduce contact resistance in wide band gap semiconductor, a thin film  $\text{GaP}_x\text{N}_{1-x}$  ( $0.1 \leq x \leq 0.9$ ) layer whose band gap is very small or equal to zero is inserted. Thereby a potential barrier formed between an electrode and a surface layer is remarkably reduced, and ohmic contact is very easily obtained. The values of thickness, composition, etc., of the  $\text{GaP}_x\text{N}_{1-x}$  ( $0.1 \leq x \leq 0.9$ ) layer between an AlGaInP based layer and the electrode are different from the carrier concentration and the composition (band gap) of a layer composed of AlGaInP based layer, and therefore not specially limited. Usually the desirable thickness is necessary only for satisfying the effect that the contact resistance is reduced.



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CLAIMS

[Claim(s)]

[Claim 1] The semiconductor device characterized by having  $1-\text{GaP}_x\text{N}_x$  ( $0.1 \leq x \leq 0.9$ ) layer of a thin film between the layers and electrodes which consist of an AlGaInN system.

[Claim 2] The semiconductor device according to claim 1 characterized by the layer which consists of this AlGaInN system being p mold.

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## DETAILED DESCRIPTION

## [Detailed Description of the Invention]

[0001]

[Industrial Application] Especially this invention relates to the semiconductor device which reduced especially contact resistance greatly about a semiconductor device about light emitting devices, such as blue which used the gallium nitride system ingredient - green light emitting diode, and blue - green laser diode.

[0002]

[Description of the Prior Art] There is that of a \*\*\*\* better potato in progress of a raise in the brightness of the latest blue and green light emitting diode (LED), and the ZnSSe system and the AlGaInN system are used as an ingredient. When high concentration p mold doping to growth and the GaN system of the quality gallium nitride (GaN) system compound semiconductor film to a substrates top, such as sapphire and SiC, was attained now, the blue light emitting diode of high brightness is realized, and double hetero structure as shown in drawing 2 is used.

[0003]

[Problem(s) to be Solved by the Invention] However, since GaN ( $E_g=3.39\text{eV}$ ) of a wideband gap is used for the surface contact layer as shown in drawing 2, a potential barrier with an electrode tends to become large, and this causes the increment in operating voltage (in the case of drawing 3 and n mold, for Fermi level and EV, the energy of the bottom of a valence band and  $q\phi_B$  are [ EC / the energy of the bottom of a conduction band, and EF ] a potential barrier). There is the technique of inserting first the layer which carried out the heavy dope directly under an electrode, namely, forming metal-n+-n and the structure metal-p+-p Becoming with such a wideband gap semi-conductor, in order to lower contact resistance (when it is drawing 4, however n mold). Since a depletion layer becomes thin very much and a carrier can pass by the tunnel effect freely, it stops thereby, showing resistance, although a potential barrier remains. Although hole concentration can dope to the high concentration of 1019 sets in the n mold GaN, on the other hand, it enters only to 1017-set level by the present condition with p mold GaN doping. For this reason, especially the layer that consists of a p mold AlGaInN is difficult for implementation of sufficiently low contact resistance. The increment in this operating voltage leads to generation of heat of a component, and this poses a big problem in order to shorten a life.

[0004]

[Means for Solving the Problem] In producing the AlGaInN system LED by MOCVD or the MBE method, we came to solve the above-mentioned technical problem by inserting 1-GaP<sub>x</sub>N<sub>x</sub> ( $0.1 \leq x \leq 0.9$ ) layer of a thin film between the layers and electrodes which consist of an AlGaInN system. This reason is that it has the special band structure that a band gap will decrease and a band gap will become zero by middle presentation whether GaPN makes P presentation increase from GaN or it makes N presentation increase from GaP. Then, even if it cannot make carrier concentration very high with a wideband gap semi-conductor by inserting 1-GaP<sub>x</sub>N<sub>x</sub> ( $0.1 \leq x \leq 0.9$ ) layer of the thin film which is zero or a band gap is very small in order to lower contact resistance, the potential barrier formed between an electrode and a surface layer is reduced sharply, and it thinks very for becoming easy to take ohmic contact (in the case of drawing 5 and n mold).

[0005] As 1-GaP<sub>x</sub>N<sub>x</sub> ( $0.1 \leq x \leq 0.9$ ) layer of the thin film between the layers and electrodes which consist of an AlGaInN system which is the main point of this invention Although it is not limited especially since it changes about values, such as thickness and a presentation, with the carrier concentration of a layer and the presentations (band gap) which consist of an AlGaInN system, as usually suitable thickness That there should just be thickness required to fulfill the effectiveness that contact resistance falls, it is usually 1 micrometer or less, and is often used by the thickness of about 5-100nm.

[0006] Moreover, as a more suitable mixed-crystal ratio x, it is 0.9 or less [ 0.1 or more ], and is 0.8 or less [ 0.2 or more ] more preferably. In addition, with the layer which consists of an AlGaInN system in this specification, the presentation of aluminum or In shall contain the thing of 0. Hereafter, although this invention is explained more to a detail using an example, this invention is not limited to an example, unless the summary is exceeded. (Example) The configuration of the equipment used for growth of this invention prepares a substrate conveyance room in the center, as shown in drawing 6, and it has installed one substrate operating room and three reduced pressure MOCVD systems. A deposition chamber 1 is the usual MOCVD system, and is used for growth of an AlGaInN system compound semiconductor. Although a deposition chamber 2 is also the usual MOCVD system, it uses for growth of groups III-V semiconductor other than an AlGaInN system. A deposition chamber 3 can understand a raw material by the radical by microwave excitation, and uses it for the nitriding on the front face of a substrate, and growth of an AlGaInN system compound. A growth procedure is shown for the epitaxial wafer of structure as shown in drawing 1.

[0007] First, silicon on sapphire is introduced into a deposition chamber 3, and carries out a heating temperature up. In 500-degreeC, radical nitrogen is supplied to a substrate front face by microwave excitation by using nitrogen gas (N<sub>2</sub>) as a raw material before growth, and the process which makes a surface oxygen (O) atom permute by N atom, i.e., nitriding, is performed. On this front face, 20nm of GaN buffer layers is grown up. Then, a substrate is cooled and a substrate is moved to a deposition chamber 1 through a conveyance room. It heats at the growth temperature C of 1000 degrees, and sequential growth of 4 micrometers of n mold GaN buffer layers, 1 micrometer of n mold aluminum<sub>0.2</sub>Ga<sub>0.8</sub>N cladding layers, 0.1 micrometers of Zn dope In<sub>0.1</sub>Ga<sub>0.9</sub>N barrier layers, 1 micrometer of p mold aluminum<sub>0.2</sub>Ga<sub>0.8</sub>N cladding layers, and the 1 micrometer of the p mold GaN contact layers is carried out on said epitaxial film growth substrate. At this time, hydrogen was used for carrier gas and trimethylgallium (TMG), trimethylaluminum (TMA), and trimethylindium (TMI) were used for III group material gas. Although ammonia (NH<sub>3</sub>) is generally used for V group raw material, organic metals, such as dimethylhydrazine with the sufficient decomposition effectiveness in low temperature and horse mackerel-ized ethyl, may be used for reduction of growth temperature. Si or germanium was used for n mold dopant, and Mg or Zn was used for p mold dopant. If needed, it continues after growth, and heat-treats in the growth interior of a room, and a carrier is activated. Then, a substrate is cooled and a substrate is moved to a deposition chamber 2 through a conveyance room. A substrate is heated to 700-degreeC and GaP<sub>0.2</sub>N<sub>0.8</sub> with a thickness of 20nm is grown up as a contact resistance reduction layer on said epitaxial film growth substrate. At this time, hydrogen was used for carrier gas and NH<sub>3</sub> and a phosphine (PH<sub>3</sub>) were used for V group raw material for TMG at III group material gas. Although said GaP<sub>0.2</sub>N<sub>0.8</sub> contact-resistance reduction layer will enlarge the absorption of light which emitted light when it was made not much thick, it is very effective in reduction of contact resistance like the above-mentioned example also at a very thin thin film without the effect of light absorption. Moreover, since this contact resistance reduction layer has very

small resistivity, the role which extends a current on a front face is also given sure enough.

[0008] Thus, the electrode was formed in the front-face side of the grown-up epitaxial wafer, and it was processed into the chip. When this chip was assembled as light emitting diode and made to emit light, in 20mA of forward current, the luminescence wavelength of 420nm, and 800 microwatts of radiant power outputs and a very good value were acquired. At this time, operating voltage was 3.3V and operating voltage was 4.0V in the conventional light emitting diode in which the electrode was formed on the p-GaN front face produced for the comparison. Reduction of this operating voltage meant the fall of generation of heat of the component itself, and has improved the life of a component greatly.

[0009] Although the above-mentioned example was about light emitting diode, to say nothing of there being the same effectiveness also as semiconductor laser, about all the semiconductor devices that install a direct electrode on an AlGaInN system semi-conductor layer in addition to this, the loss by reduction in resistance can be reduced and effectiveness is demonstrated.

[0010]

[Effect of the Invention] When resistance is reduced and this is used as luminescence equipment by inserting 1-GaP<sub>x</sub>N<sub>x</sub> (0.1≤x≤0.9) layer of a thin film between the layers and electrodes which consist of an AlGaInN system, operating voltage can be reduced greatly and the property of the AlGaInN system light emitting device of ultraviolet - red and the life of a component can also be improved sharply.

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DESCRIPTION OF DRAWINGS

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[Brief Description of the Drawings]

[Drawing 1] Drawing 1 is the explanatory view showing an example of the semiconductor device of this invention.

[Drawing 2] Drawing 2 is the explanatory view showing an example of the conventional semiconductor device.

[Drawing 3] Drawing 3 is the explanatory view of the energy band at the time of installing a direct electrode on the conventional AlGaInN system semi-conductor layer.

[Drawing 4] Drawing 4 is the explanatory view of the energy band at the time of preparing a heavy dope layer on the conventional AlGaInN system semi-conductor layer, and installing an electrode on it.

[Drawing 5] Drawing 5 is the explanatory view of the energy band at the time of inserting 1-GaP<sub>x</sub>N<sub>x</sub> (0.1<=x<=0.9) layer, and installing an electrode on the AlGaInN system semi-conductor layer of this invention.

[Drawing 6] Drawing 6 is the explanatory view of a manufacturing installation used in the example 1.

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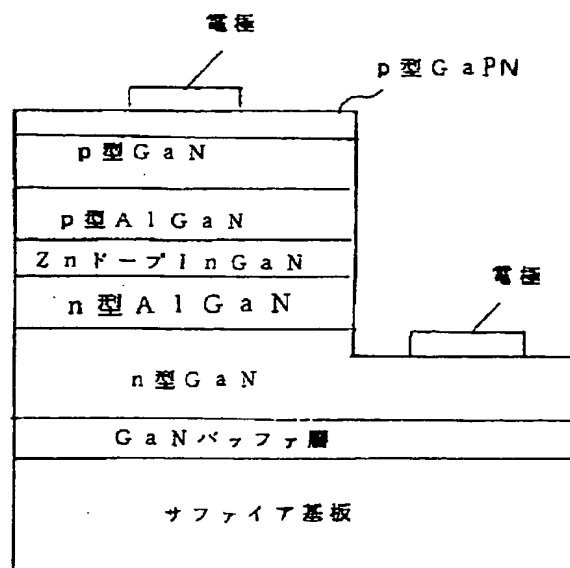
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(54)【発明の名称】 コンタクト抵抗低減層を有する半導体装置

(57)【要約】

【課題】 AlGaInN系からなる層と電極との間の抵抗値を低減することにより、特性の向上した半導体装置、特に高輝度の青又は緑色の半導体発光装置を提供する。

【解決手段】 AlGaInN系からなる層と電極との間に薄膜のGaP<sub>x</sub>N<sub>1-x</sub> (0.1 ≤ x ≤ 0.9) 層を挿入したことを特徴とする半導体装置。



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## 【特許請求の範囲】

【請求項1】 AlGaInN系からなる層と電極との間に薄膜のGaP<sub>1-x</sub>N<sub>x</sub> (0.1 ≤ x ≤ 0.9) 層を有することを特徴とする半導体装置。

【請求項2】 該AlGaInN系からなる層がp型であることを特徴とする請求項1記載の半導体装置。

## 【発明の詳細な説明】

【0001】

【産業上の利用分野】 本発明は半導体装置に関し、特に窒化ガリウム系材料を使用した青色～緑色発光ダイオード、青色～緑色レーザーダイオード等の発光素子に関し、特に接触抵抗を大きく低減した半導体装置に関する。

【0002】

【従来の技術】 最近の青色及び緑色の発光ダイオード(LED)の高輝度化の進展には目ざましいものがあり、材料として、ZnSSe系やAlGaInN系が用いられている。現在、サファイア、SiCなどの基板上への高品質な窒化ガリウム(GaN)系化合物半導体膜の成長とGaN系への高濃度p型ドーピングが可能となったことにより、高輝度の青色発光ダイオードが実現されており、図2に示すようなダブルヘテロ構造が用いられている。

【0003】

【発明が解決しようとする課題】 しかしながら、図2に示すように、表面コンタクト層にワイドバンドギャップのGaN (E<sub>g</sub> = 3.39 eV) を用いているために、電極との電位障壁が大きくなりやすく、このことが動作電圧の増加を招いてしまう(図3、n型の場合、E<sub>c</sub>は伝導帯の底のエネルギー、E<sub>f</sub>はフェルミ準位、E<sub>v</sub>は価電子帯の底のエネルギー、φ<sub>0</sub>は電位障壁)。このようなワイドバンドギャップ半導体で、接触抵抗を下げるには、まず、ヘビードープした層を電極直下に挿入する、すなわちmetal-n+n、metal-p+pなる構造を形成する手法がある(図4、ただし、n型の場合)。これにより、電位障壁は残るが、非常に空乏層が薄くなり、キャリアが自由にトンネル効果で通過できるため、抵抗を示さなくなる。n型GaNではホール濃度が10<sup>19</sup>台という高濃度までドーピングが可能であるが、一方p型GaNドーピングでは、現状では10<sup>17</sup>台レベルまでしか入らない。このために、特にp型AlGaInN系からなる層とは、充分低い接触抵抗の実現は困難である。この動作電圧の増加は、素子の発熱につながり、これは寿命を短くするため大きな問題となる。

【0004】

【課題を解決するための手段】 我々は、MOCVDやMBE法でAlGaInN系LEDを作製するにあたり、AlGaInN系からなる層と電極との間に薄膜のGaP<sub>1-x</sub>N<sub>x</sub> (0.1 ≤ x ≤ 0.9) 層を挿入することにより、上記の課題を解決するに至った。この理由は、Ga

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PNは、GaNからP組成を増加させても、またGaPからN組成を増加させてもバンドギャップが減少し、中間組成でバンドギャップがゼロになってしまうという特殊なバンド構造を有しているからである。そこで、ワイドバンドギャップ半導体で、接触抵抗を下げるために、非常にバンドギャップが小さいもしくはゼロである薄膜のGaP<sub>1-x</sub>N<sub>x</sub> (0.1 ≤ x ≤ 0.9) 層を挿入することにより、キャリア濃度を非常に高くすることができなくても、電極と表面層との間で形成される電位障壁が大幅に低減され、オーミックコンタクトを非常に取り易くするためと考えられる(図5、n型の場合)。

【0005】 本発明の要点であるAlGaInN系からなる層と電極との間の薄膜のGaP<sub>1-x</sub>N<sub>x</sub> (0.1 ≤ x ≤ 0.9) 層としては、厚さ、組成等の値については、AlGaInN系からなる層のキャリア濃度と組成(バンドギャップ)により異なるため特に限定されないが、通常好適な厚さとしては、接触抵抗が低下するという効果を満たすのに必要な厚さがあればよく、通常1 μm以下であり、しばしば5～100 nm程度の厚さで使用される。

【0006】 又より好適な混晶比xとしては、0.1以上0.9以下であり、より好ましくは0.2以上0.8以下である。尚、本明細書においてAlGaInN系からなる層とは、Al又はInの組成が0のものを含むものとする。以下、本発明を実施例を用いてより詳細に説明するが、本発明はその要旨を超えない限り、実施例に限定されるものではない。

(実施例) 本発明の成長に使用した装置の構成は図6に示すように中央に基板搬送室を設け、基板交換室1室と減圧MOCVD装置3台を設置してある。成長室1は通常のMOCVD装置であり、AlGaInN系化合物半導体の成長に用いる。成長室2も通常のMOCVD装置であるがAlGaInN系以外のIII-V族化合物半導体の成長に用いる。成長室3は、原料をマイクロ波励起によりラジカル分解することができ、基板表面の窒化及びAlGaInN系化合物の成長に用いる。図1に示すような構造のエピタキシャルウエハを成長手順を示す。

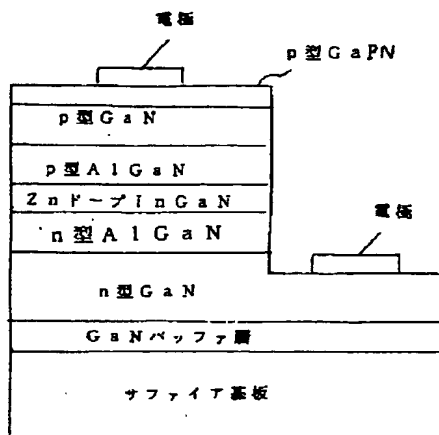
【0007】 まずサファイア基板を成長室3に導入し、加熱昇温する。500°Cにおいて、成長前に窒素ガス(N<sub>2</sub>)を原料として、マイクロ波励起によりラジカル窒素を基板表面に供給し、表面の酸素(O)原子をN原子と置換させる工程、すなわち窒化を行う。この表面上に、GaNバッファ層20 nmを成長させる。その後、基板を冷却し、搬送室を経て成長室1へ基板を移動させる。成長温度1000°Cで加熱し、前記エピタキシャル膜成長基板上に、n型GaNバッファ層4 μm、n型Al<sub>0.2</sub>Ga<sub>0.8</sub>Nクラッド層1 μm、ZnドーピングIn<sub>0.1</sub>Ga<sub>0.9</sub>N活性層0.1 μm、p型Al<sub>0.2</sub>Ga<sub>0.8</sub>Nクラッド層1 μm、p型GaNコンタクト層1 μmを順

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次成長させる。このとき、キャリアガスに水素を用いて、III族原料ガスに、トリメチルガリウム(TMG)、トリメチルアルミニウム(TMA)、トリメチルインジウム(TMI)を用いた。V族原料には、一般的にはアンモニア(NH<sub>3</sub>)が用いられるが、成長温度の低減のために、低温での分解効率のよいジメチルヒドリンやアジ化エチルなどの有機金属を用いてもよい。n型ドーパントには、SiまたはGeを、p型ドーパントには、MgまたはZnを用いた。必要に応じて、成長後に引き続いて成長室内で熱処理を行い、キャリアを活性化させる。この後、基板を冷却し、搬送室を経て成長室2へ基板を移動させる。基板を700°Cに加熱し、前記エピタキシャル膜成長基板上に厚み20nmのGaP<sub>0.2</sub>N<sub>0.8</sub>を接触抵抗低減層として成長させる。このとき、キャリアガスに水素を用いて、III族原料ガスに、TMGをV族原料には、NH<sub>3</sub>及びホスフィン(PH<sub>3</sub>)を使用した。前記GaP<sub>0.2</sub>N<sub>0.8</sub>接触抵抗低減層は、余り厚くすると発光した光の吸収を大きくしてしまうが、上記実施例のように、光吸収の影響のない非常に薄い薄膜でも接触抵抗の低減に、非常に有効である。また、この接触抵抗低減層は、抵抗率が非常に小さいために、表面で電流を広げる役割も果たしてくれる。

【0008】このようにして成長したエピタキシャルウエハの表面側に電極を形成し、チップに加工した。このチップを発光ダイオードとして組み立てて発光させたところ、順方向電流20mAにおいて、発光波長420nm、発光出力800μWと非常に良好な値が得られた。このとき動作電圧は3.3Vであり、比較のために作製したp-GaN表面上に電極を形成した従来の発光ダイオードでは動作電圧が4.0Vであった。この動作電圧の低減は、素子自体の発熱の低下を意味し、素子の寿命

【図1】



4

を大きく改善できた。

【0009】上記実施例は、発光ダイオードについてであったが、半導体レーザにも同様な効果があることは言うまでもなく、そしてその他AlGaInN系半導体層の上に直接電極を設置する全ての半導体素子について、抵抗の減少によるロスを減らすことができ、効果を発揮する。

【0010】

【発明の効果】AlGaInN系からなる層と電極との間に薄膜のGaP<sub>x</sub>N<sub>1-x</sub> (0.1 ≤ x ≤ 0.9) 層を挿入することにより、抵抗を低減し、これを発光装置として用いた場合には、動作電圧を大きく低減することができ、紫外～赤色のAlGaInN系発光素子の特性及び素子の寿命も大幅に改善できる。

【図面の簡単な説明】

【図1】図1は、本発明の半導体装置の一例を示す説明図である。

【図2】図2は従来の半導体装置の一例を示す説明図である。

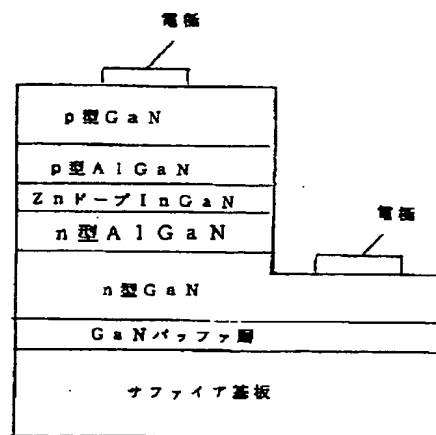
【図3】図3は、従来のAlGaInN系半導体層の上に直接電極を設置した場合のエネルギーバンドの説明図である。

【図4】図4は、従来のAlGaInN系半導体層の上にヘビードープ層を設けその上に電極を設置した場合のエネルギーバンドの説明図である。

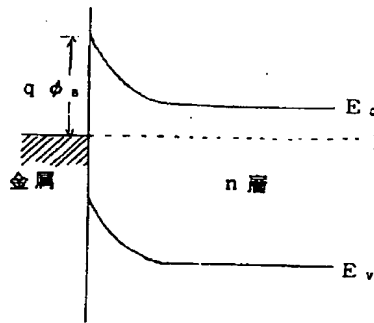
【図5】図5は、本発明のAlGaInN系半導体層の上にGaP<sub>x</sub>N<sub>1-x</sub> (0.1 ≤ x ≤ 0.9) 層を挿入して電極を設置した場合のエネルギーバンドの説明図である。

【図6】図6は、実施例1で用いた製造装置の説明図である。

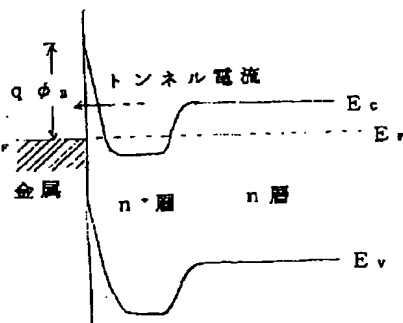
【図2】



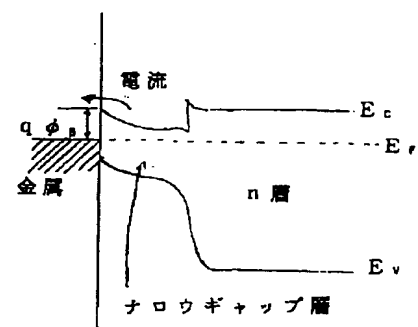
【図3】



【図4】



【図5】



【図6】

